CHAPTER 2

MEASURING AND REPAIR INSTRUMENTS

You, as an Engineman, must he able to identify the basic measuring and repair instruments and the basic components of these instruments. This chapter will help you to recognize the how and when to use and maintain basic measuring and repair instruments and engine test equipment.

Measuring instruments are used to check tolerances and specifications during inspections and repairs of internal combustion engines and auxiliary equipment. You, as an Engineman, need measuring instruments to determine what parts are worn and need to be repaired or replaced. The following measuring and repair instruments are discussed in this chapter: dial indicator, dial/vernier caliper, micrometer, snap gauge, bore gauge, strain gauge, borescope, stroboscope, torque wrench, multiplier, adapter, ridge reamer, cylinder hone, and dynamometer.

SENSITIVE MEASURING TOOLS

Sensitive measuring tools are measuring devices that provide measurement readings to a thousandth of an inch or less. The more common sensitive measuring tools you will use are the dial indicator, dial/vernier caliper, micrometer, snap gauge, bore gauge, and strain gauge.

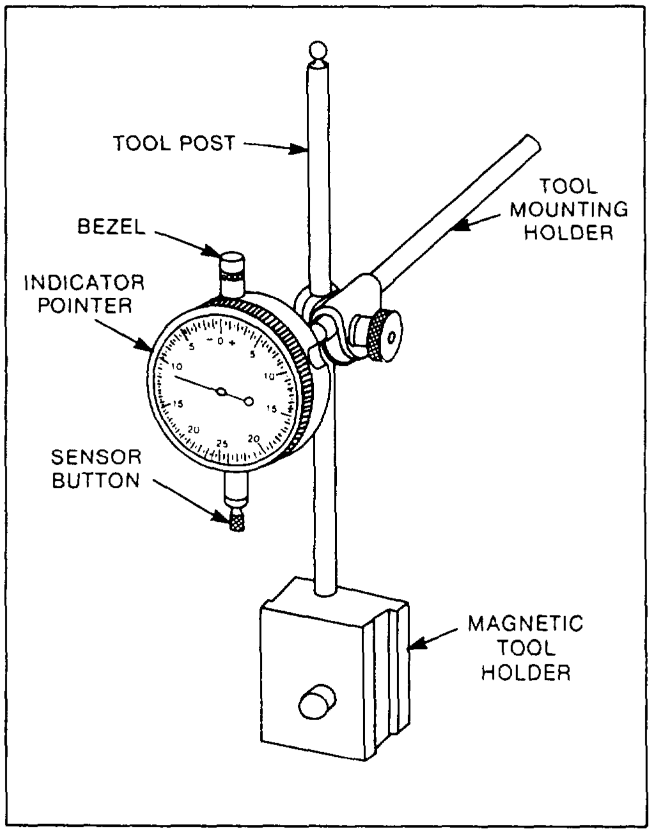


Figure 2-1.—Typical dial indicator wlth mounting accessories.

DIAL INDICATOR

A dial indicator is used to measure shaft runout, shaft thrust, gear backlash, flywheel face runout, flywheel housing concentricity, and valve seat concentricity. You can mount a dial indicator on a test stand or, with clamps and a magnetic base, directly on the equipment to be measured. Figure 2-1 shows a typical dial indicator with mounting accessories,

Most dial indicators have components such as a bezel, indicator pointer, tool post and clamp, magnetic toolholder, and sensor button that are used in taking measurements.

The following procedures explain how to use the indicator to take shaft runout and crankshaft end play measurements. Procedures for taking other measurements are similar.

Shaft Runout

When you need to measure a shaft's runout, select a suitable position on the shaft, free of keyways, corrosion, or other damage. Clean the surface and remove any burrs around scratches or dents. To take the runout measurement, use the following procedure:

1. Place the shaft in well-oiled V-blocks. If the shaft is a crankshaft, place the bearing journals in the V-blocks.

2. Attach the magnetic base to a machined surface. Mount the dial indicator on a tool mounting holder and attach the holder to the base.

3. Adjust the mounting post so you can easily read the face of the dial.

4. Move the indicator toward the shaft until the sensor button just touches the surface you wish to measure.

5. Continue moving the indicator slowly toward the shaft until the dial pointer has moved to the midpoint of its travel on the dial face.

6. Leave the pointer at midtravel and turn the bezel until the zero on the dial is aligned with the pointer.

7. You can now rotate and watch the pointer to see if it moves. The total amount the pointer moves is called the total indicator reading (TIR). If the shaft is straight, the pointer should remain at zero.

Crankshaft End Play or Thrust Readings

To measure crankshaft end play or thrust, use the following procedure:

1. Attach the dial indicator to a convenient place near the vibration damper.

2. Position the dial indicator gauge so the contact point touches the front of the vibration damper and moves the dial indicator near the midpoint of its range.

3. Insert one end of a pry bar between a main bearing cap and a crankshaft counterweight.

NOTE: DO NOT INSERT THE PRYBAR BETWEEN THE VIBRATION DAMPER AND THE BLOCK TO MEASURE THE CRANKSHAFT END PLAY. You may dent the damper and render it ineffective.

4. Move the crankshaft toward the dial indicator. Be sure to maintain a constant pressure on the prybar.

5. Set the dial indicator to zero.

6. Remove the prybar and then reinsert it on the other side of the main bearing cap.

7. Carefully pry the crankshaft in the opposite direction to measure the crankshaft end play. Repeat your measurement a minimum of two times for accuracy.

DIAL/VERNIER CALIPER

The dial/vernier caliper is used to measure the inside or outside diameter of an object. Figure 2-2 shows a typical dial/vernier caliper.

Most dial/vernier calipers have a slide, slide lockscrew, thumb button, scale, dial with measured increments of 0.001 inch, and a bezel.

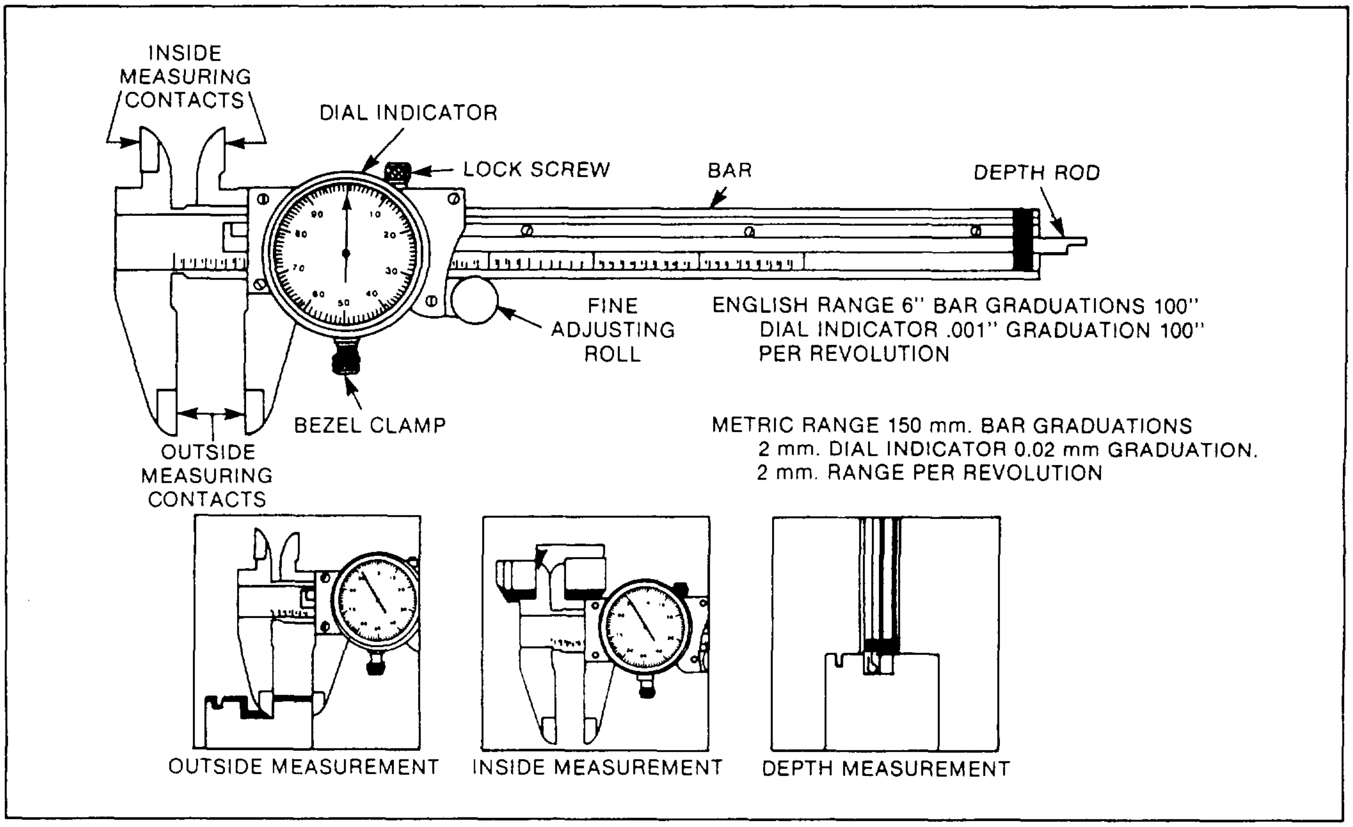


Figure 2-2.—Typical dial/vernier caliper.

For specific instructions on how to take measurements with a dial/vernier caliper, refer to either the manufacturer's instructions or to Tools and Their Uses, NAVEDTRA 10085-B2.

Regardless of what type of caliper you use, be sure to take the following precautions to avoid damaging the caliper:

1. Wash your hands before you handle the vernier caliper to remove dirt and oils that might damage the caliper.

2. Wipe the caliper components clean both before and after you use the caliper.

3. Do NOT drop or otherwise mishandle the caliper. Doing so may damage or destroy the caliper.

Figure 2-3 illustrates the use of a dial/vernier caliper in measuring the inside and outside diameters of two different components.

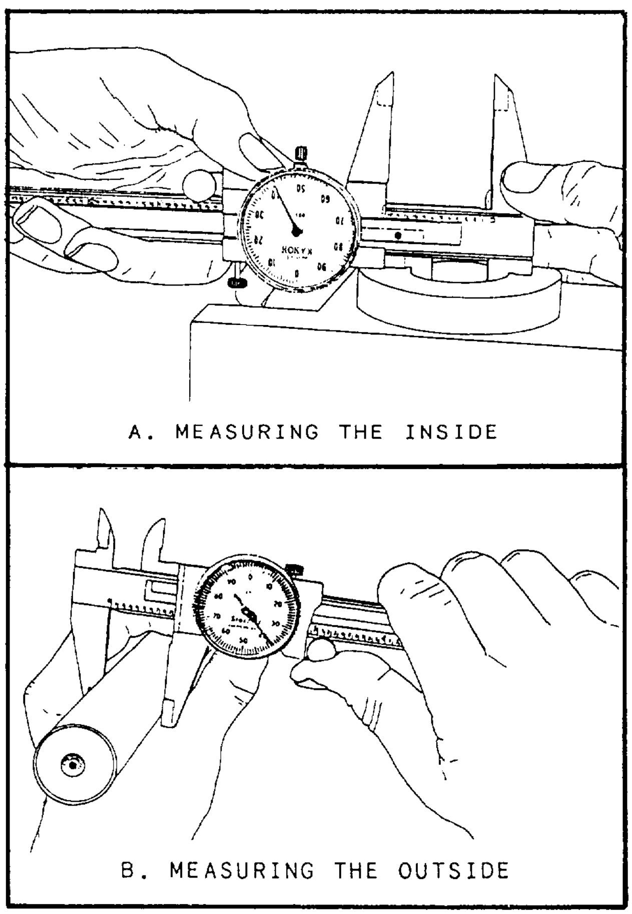


Figure 2-3.—Measuring (A) inside and (B) outside diameters with a dial/vernier caliper.

MICROMETER

The micrometer is a precision measuring instrument used to measure distances between surfaces in thousandths of an inch Figure 2-4 shows the most common types of micrometers.

Most micrometers have a frame, anvil, spindle, sleeve, thimble, and ratchet stop.

Micrometers are used to measure the outside diameters; inside diameters; the distance between parallel surfaces; the depth of holes, slots, counterbores, and recesses; and the distance from a surface to some recessed part. There are other uses of micrometers, but those mentioned here are uses you are most likely to encounter. Instructions on how to read a micrometer are given in the manufacturer's owner's manual and Tools and Their Uses, NAVEDTRA 10085-B2.

Whenever you use a micrometer, carefully observe the "DO's" and "DON'Ts" in the following list to obtain accurate measurements and to protect the instrument:

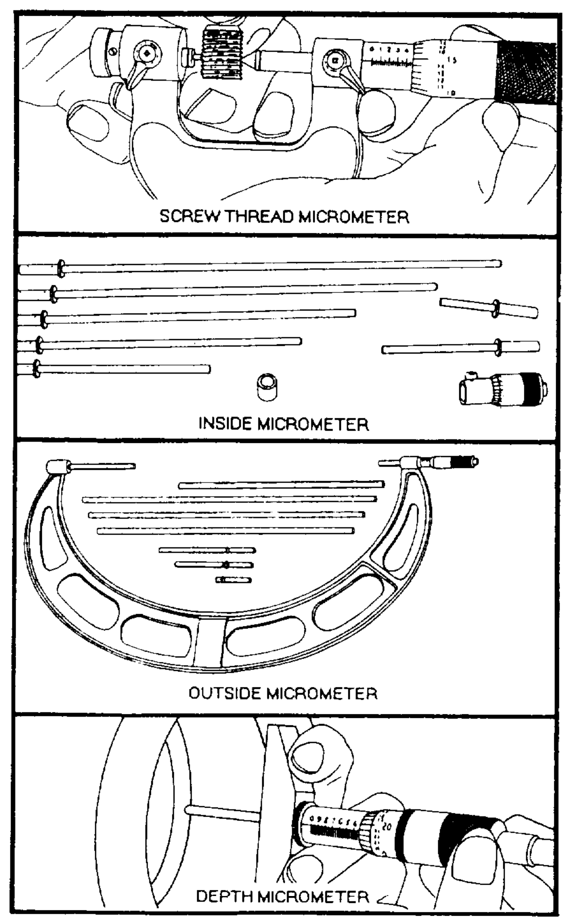


Figure 2-4.—Common types of micrometers.

1. Always stop the work before you take a measurement. DO NOT measure moving parts because the micrometer may get caught in the rotating work and be severely damaged.

2. Always open a micrometer by holding the frame with one hand and turning the knurled sleeve with the other hand. Never open a micrometer by twirling the frame, because such practice will put unnecessary strain on the instrument and cause excessive wear of the threads.

3. Apply only moderate force to the knurled thimble when you take a measurement. Always use the friction slip ratchet if there is one on the instrument. Too much pressure on the knurled sleeve will not only result in an inaccurate reading, but also will cause the frame to spring and force the measuring surface out of line.

4. When a micrometer is not in use, place it where it will not drop. Dropping a micrometer will cause the micrometer frame to spring. If you drop a micrometer, check it for accuracy before you take further readings.

5. Before you store a micrometer, back the spindle away from the anvil, wipe all exterior surfaces with a clean, soft cloth, and coat the surfaces with a light oil. Do not reset the measuring surfaces to close contact because the protecting film of oil on these surfaces will be squeezed out.

SNAP GAUGE

The snap gauge compares the outside diameters of parts such as shafts and journals to a standard. It can compare diameters from zero to 8 inches at an accuracy of 0.0001 inch. Figure 2-5 shows a typical snap gauge.

Most snap gauges consist of a frame with an insulated handle, a hex wrench mounted in the handle, dial indicator digits calibrated in 0.00l-inch divisions, a bezel clamp, adjustment wheels, locking wheels, a backstop, a lower anvil, an upper anvil, and a guard.

Whenever you use a snap gauge, use the handle and avoid touching the gauge proper because body heat may affect the reading. For the same reason, handle the standard plugs only by their plastic end. Clean the anvils and the backstop with a clean cloth. To use the snap gauge, follow the manufacturer's operating instructions.

After you record the readings and compare the readings with the design specifications, clean and store the snap gauge in its appropriate storage location.

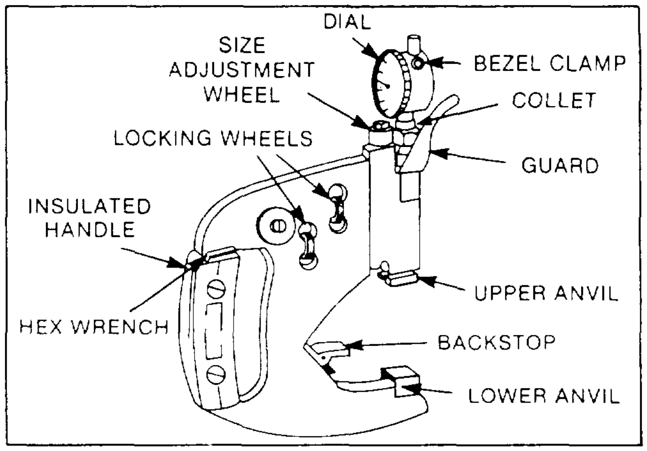


Figure 2-5.—Typical snap gauge.

BORE GAUGES

The dial bore gauge is one of the most accurate tools for measuring a cylindrical bore or for checking a bore for out-of-roundness or taper. The gauge does not give a direct measurement. It identifies the amount of deviation from a preset size or the amount of deviation from one part of the bore to another. A master ring gauge, outside micrometer, or vernier caliper can be used to preset the gauge. Figure 2-6 shows a typical bore gauge.

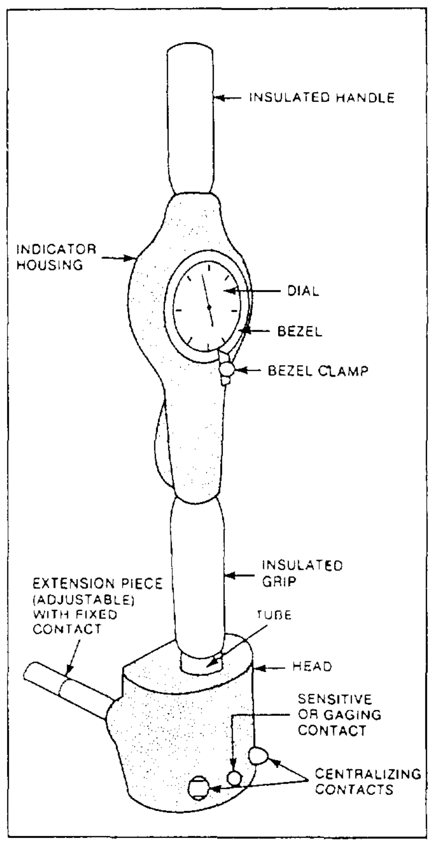


Figure 2-6.—Typical bore gauge.

Most bore gauges consist of a dial indicator, extension pieces, bezel and locknut, spring-loaded guide, and sensor button.

Before you start a measuring procedure, expose both the bore gauge and the master ring gauge, or any other tools used to preset the bore gauge, and the part to be measured to the same work place environment for one hour. If you fail to do this, a temperature differential may cause your readings to be inaccurate. When you use the bore gauge, touch only its insulated handle.

The gauge has two stationary spring-loaded points and an adjustable point to permit a variation in range. These points are evenly spaced to allow accurate centering of the tool in the bore. A fourth point, the tip of the dial indicator, is located between the two stationary points. By simply rocking the tool in the bore, you can observe the amount of variation on the dial. Figure 2-7 shows a bore gauge inside a bore being moved in a gentle rocking motion. Always follow the bore gauge manufacturer’s operating manual. Measure the bore and mark the areas you measure. A good practice is to check the bore gauge in the standard after you take each set of measurements to ensure that readings are accurate.

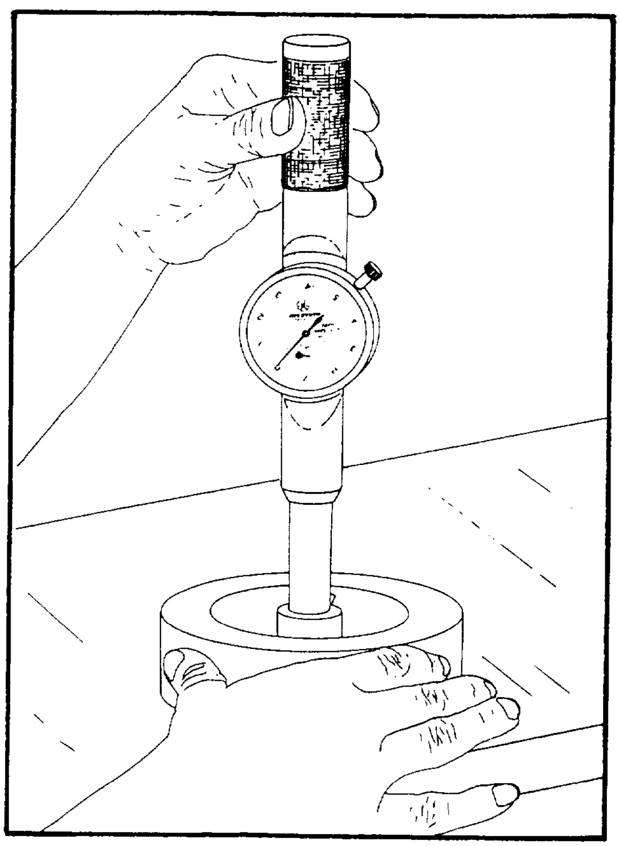


Figure 2-7.—Measuring a bore with a bore gauge.

STRAIN/DEFLECTION GAUGE

A strain or deflection gauge is used to check the crankshaft alignment on large diesel engines. It is a specially adapted dial indicator that fits between the crank webs. The strain gauge reads the flexing motion of the webs directly as the crankshaft is slowly rotated (correct engine rotation). The gauge dial reads in 0.00l-inch graduations.

The strain gauge consists of a dial indicator, contact point, balancing attachment, clamping nut, spring plunger, rods and extension, and bezel.

Before you take a reading, be sure the engine is completely assembled and cold. Place the strain gauge between the webs of a crankthrow, as far as possible from the axis of the crankpin. The ends of the indicator should rest in the prick-punch marks in the crank webs. If these marks are not present, consult the manufacturer’s technical manual for the proper location of the marks. Ensure that the strain gauge is at the same temperature as the engine. A temperature differential may cause inaccurate readings. Readings are generally taken at the four crank positions; top dead center, inboard, near or at bottom dead center, and outboard However, the manufacturer’s technical manual for the specific engine provides information concerning the proper positions of the crank for taking readings. In some situations, due to the position of the dial, you may need to use a mirror and a flashlight to read the gauge. Once you have placed the indicator in position for the first reading, DO NOT touch the gauge until you have taken and recorded all four readings. Variations in the readings taken at the four crank positions indicate distortion of the crank, which may be caused by any of several factors, such as a bent crankshaft, worn bearings, or improper engine alignment. The manufacturer’s technical manual will provide you with the maximum allowable deflection. Figure 2-8 shows the locations for taking crankshaft deflection readings.

BORESCOPE

A borescope is used to inspect internal parts on an engine without having to disassemble the engine. This instrument helps a great deal in estimating the amount of repair work needed and the time required for the repair. Figure 2-9 shows a typical borescope.

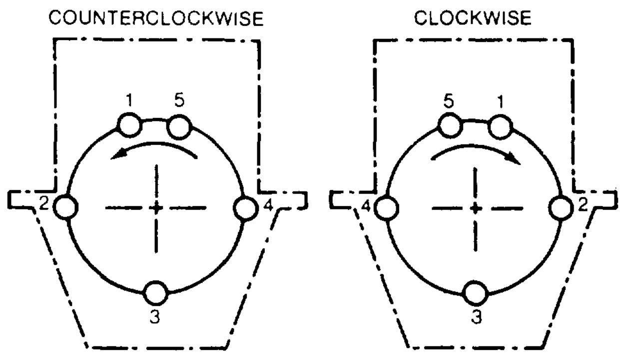


Figure 2-8.—Locations for taking crankshaft deflection readings.

Most borescopes have the following basic components:

1. Eyepiece (zoom or wide angle)
2. Scan control ring
3. Probe tube
4. Scan mirror
5. Quartz-lined lamp
6. Focus control ring
7. Other electrical accessories

As with any optical instrument, you should handle the borescope with care to avoid damaging its lenses and mirrors. The borescope is powered by alternating current. So, before you first use it, be sure to read and follow the manufacturer's operating instructions. The borescope can be inserted through any engine opening, such as a cylinder port, to identify problems, such as cracked pistons, cracks in the cylinder head, burned valves, and scuffed or pitted liners. You can remove the crankcase cover to inspect the bottom section of the engine.

STROBOSCOPE

A stroboscope is a flashing light source used to measure the speed of fast-moving objects. it produces the optical effect of stopping or slowing down an object to allow you to observe and analyze the object's motion. Figure 2-10 shows a typical stroboscope.

A stroboscope consists of a power switch, rpm control dial, range switch, calibration indicator light, calibration screws, combination adjustments, reflector lamp assembly, and other electrical accessories. For information about the functions of the components, consult the operator's manual.

Before you use the stroboscope, be sure to read and follow the manufacturer's operating instructions. The instrument commonly operates from a 120-volt, 60-Hz, alternating current supply. Any change in current frequency will affect the flashing speed and affect the stroboscope's accuracy for speed measurements. The stroboscope can be used to measure the speed and to observe the motion of rotating, reciprocating, or vibrating mechanisms. Never leave the stroboscope unattended while it is in use. Since the stroboscope makes a moving object appear to be standing still, someone could be seriously injured by the apparently "stationary" object.

TORQUE WRENCH

The torque wrench is used to measure an object's resistance to turning and to provide precise tightening

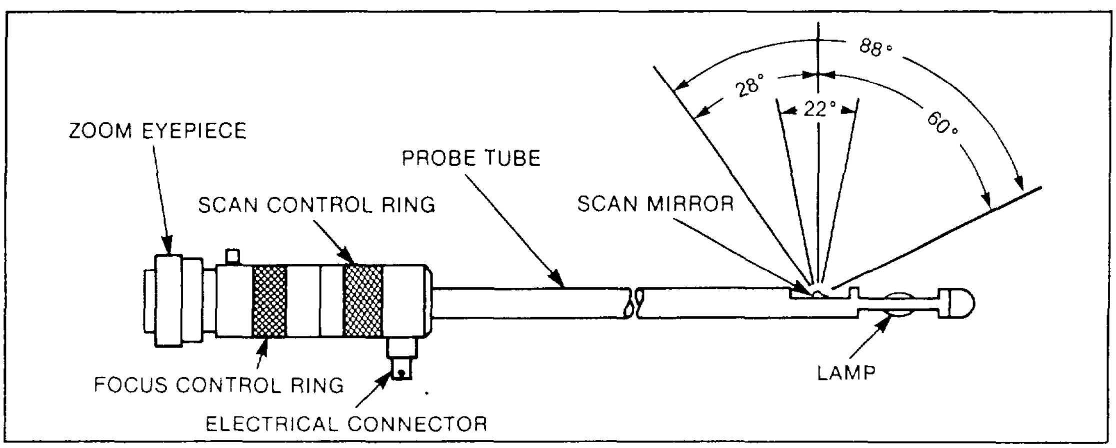


Figure 2-9.—Typical borescope.

of threaded fasteners. Figure 2-l1 shows three types of torque wrenches.

To use a torque wrench, first select the proper torque value for the torquing procedure you are using. Next,

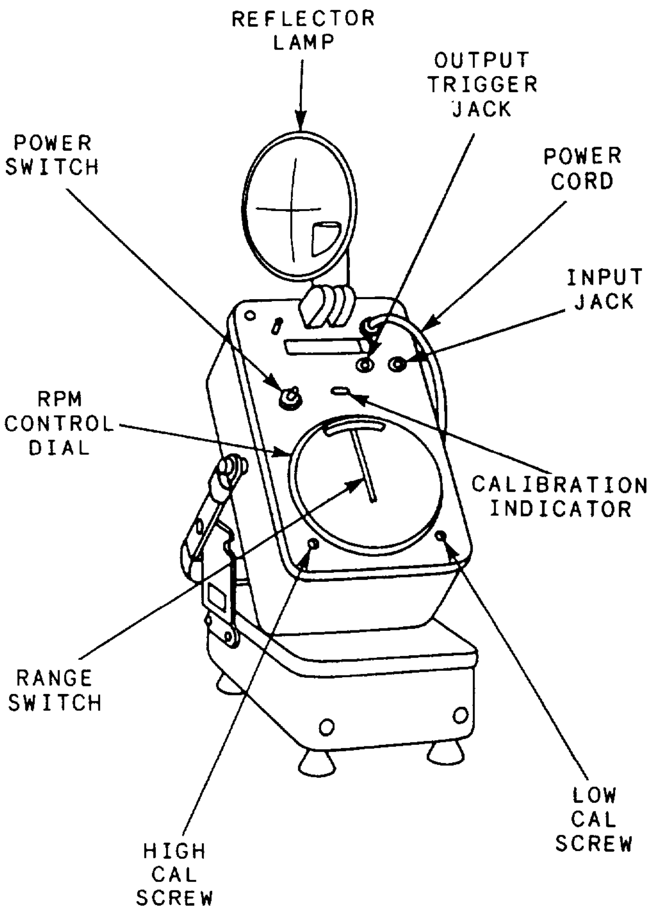


Figure 2-10.—A typical stroboscope.

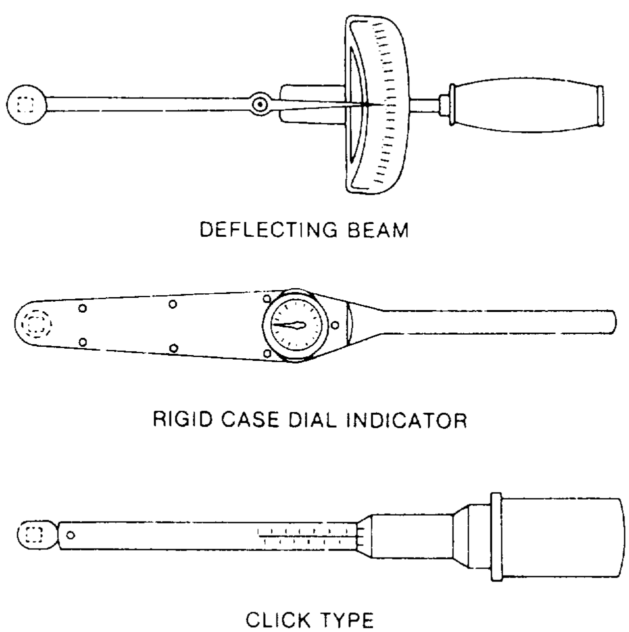


Figure 2-11.—Typical torque wrenches.

select the torque wrench with the correct capacity. The torque value should be in the second or third quarter of the wrench’s torque scale because the first and last quarters of the scale are not as accurate as the middle quarters.

Torque wrenches are precision tools. Handle them with care and always follow the manufacturer’s manual when you use them.

TORQUE MULTIPLIER

Torque multipliers are geared devices attached to the torque wrench to increase the force of torque. The most preferred ratio of the torque multiplier is 4 to 1. To use a torque multiplier, select one with an output capacity above the required torque. Be sure to follow the manufacturer’s operating manual to avoid personnel injury and damage to the equipment.

TORQUE ADAPTERS

Torque adapters allow the torque wrench to be used to tighten parts and fasteners other than standard nuts and bolts. Adapters are available in a variety of shapes geared to the repair of different parts of the diesel engine. Several types of torque adapters are shown in figure 2-12.

When you use an extension adapter, the torque applied to the part or fastener will be greater than the torque indicated on the torque wrench. Therefore, you must account for the length of the adapter to apply the proper torque to the part or fastener. Figure 2-13 illustrates the points of measurement.

The torque applied by the adapter is directly related to the length of the adapter. As the length of the adapter increases, so does the applied torque.

To determine the actual torque applied to the part or fastener, assume that the length of the torque wrench is L and the length of the adapter is A. Assume also that Tw is the torque indicated on the scale of the torque wrench and Ta is the torque exerted at the end of the adapter.

To determine Ta, simply multiply the torque indicated on the torque wrench (Tw) by the ratio of the total effective length of the assembly (L + A) to the length of the torque wrench (L).

or

$$: Tw\ x\ \frac{(L+A)}{L}$$

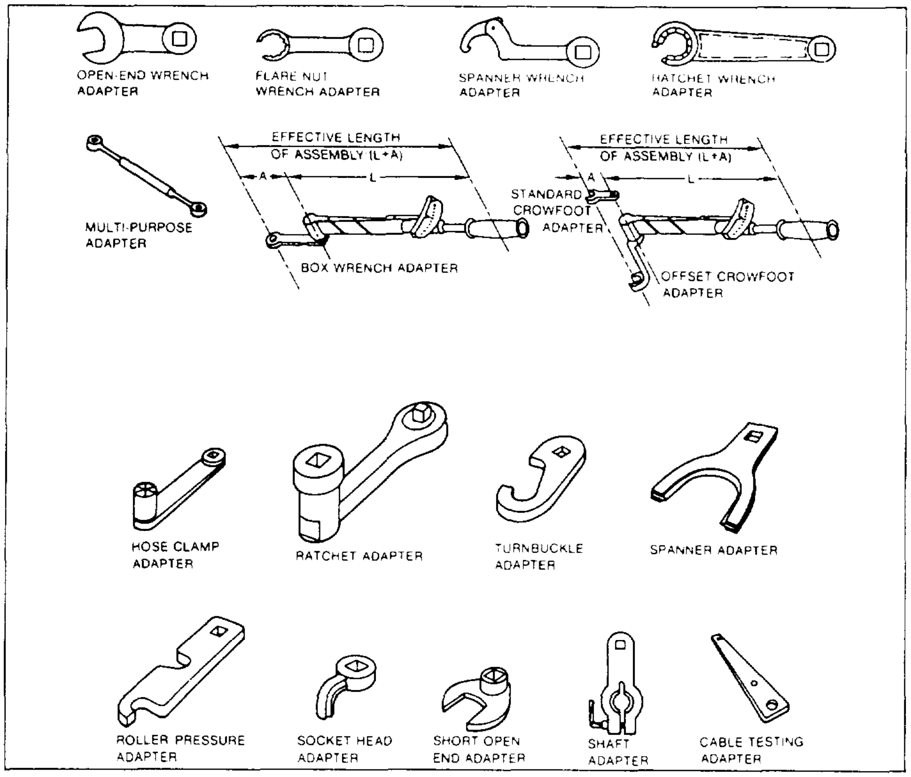


Figure 2-12.—Torque adapters.

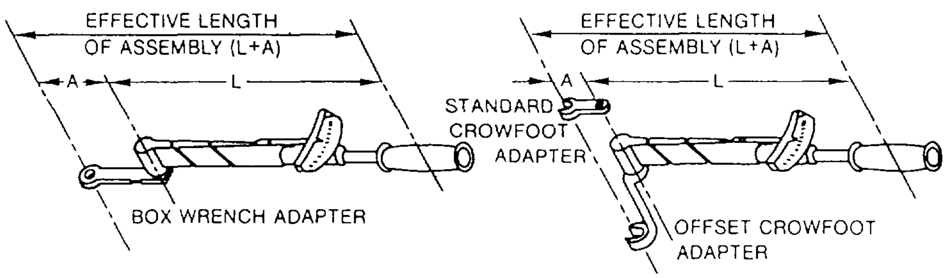


Figure 2-13.—Torque adapters and points of measurement.

An easy to remember rule of thumb is that the applied torque will be greater than the indicated torque by an amount equal to the length of the adapter compared to the length of the torque wrench. For example, if the adapter is the same length as the torque wrench, the applied torque will be twice as great as the indicated torque. If the adapter is one-third as long as the torque wrench, the applied torque will be one-third greater than the indicated torque.

Figures 2-14 and 2-15 illustrate how to calculate applied torque.

RIDGE REAMER

A ridge reamer is used to remove ridges formed at the tops of cylinders produced by piston rings moving up and down in the cylinders. Figure 2-16 illustrates a typical ridge reamer.

The ridge reamer consists of a carbon cutter, adjustable guides, adjustable cutter head, adjustable cutter, and threaded feed screw.

Whenever you use a ridge reamer, you must wear eye protection, such as a face shield or goggles.

Determining Applied torque	$Ta = Tw\ x \frac{(L+A)}{L}$ Ta = Torque exerted at the end of the adapter Tw = Wrench scale reading L = Lever length of the wrench A = Length of the adapter
Determining Indicated Torque (when desired torque is known)	$Tw = \frac{Ta\ x\ L}{(L+A)}$ Tw = Wrench scale reading Ta = Torque exerted at end of the adapter L = Lever length of the wrench A = Length of the adapter
Determining Adapter or Extension Length	$A = \frac{(Ta - Tw)\ x\ L}{Tw}$ A = Length of the adapter Ta = Torque exerted at end of the adapter Tw = Wrench scale reading L = Lever length of the wrench
At times it is necessary to calculate the wrench scale reading for several torques using the same wrench and adapter assembly. In such cases, it is convenient to determine a CONVERSION CONSTANT for the assembly which will simplify calculations.	The following formula shows the constant: $C = \frac{L}{L+A}$ CONVERSION CONSTANT C = Conversion constant for wrench and adapter assembly
This constant is a ratio of the lever length of the torque wrench to the total effective length of the assembly.	L = Lever length of wrench A = Length of adapter

Figure 2-14.—Torque calculation for eithcr adapters or extensions.

Remember that the cutter will take out the ridge with a lathelike cutting action. Read and follow the manufacturer's manual on how to use the reamer. After all the ridges are removed, take a measurement with a bore gauge, and verify that the cylinder is within specifications.

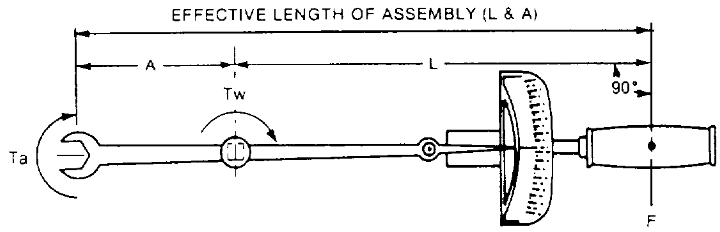
CYLINDER HONE

To reuse the cylinder sleeve, you must refinish the glazed surface caused by piston ring travel. Honing will remove high spots and a slight taper or out-of-roundness. Do not hone new or chromium-plated liners unless specified by the liner manufacturer. Figure 2-17 shows a typical cylinder hone.

Before you use a cylinder hone, read or review the operator's manual. When you use a hone, use only an approved cleaning solvent and ensure that there is adequate ventilation in the work area. When solvent fumes are present, do not allow eating, drinking, smoking, open flames, or lights in the work area. Dispose of hazardous materials, such as solvent-soaked rags and used solvents, properly.

Torque wrenches so constructed that the position of applied load can be varied on the frame or handle of the wrench WILL NOT work correctly with adapters or extensions.

The following calculations or formulas apply to either adapters or extensions having the axis of their work engaging member intersecting the extended center line of the torque wrench frame.



"Tw" is the torque indicated on the scale of the torque wrench and "Ta" is the torque exerted at the end of the adapter.

To calculate the TORQUE PRODUCED AT THE END OF THE ADAPTER (Ta) it is necessary to multiply the total effective length of the assembly (L plus A) by the force (F) exerted on the torque wrench handle.

$$Ta = (L + A) \times F$$

THE FORCE (F) EXERTED ON THE HANDLE OF THE WRENCH EQUALS THE TORQUE developed by the wrench at "Tw" . . . which is the torque indicated on the scale . . . divided by the lever length of the wrench (L).

$$F = \frac{Tw}{L}$$

ADAPTER FORMULA

Figure 2-15.—How to calculate applied torque.

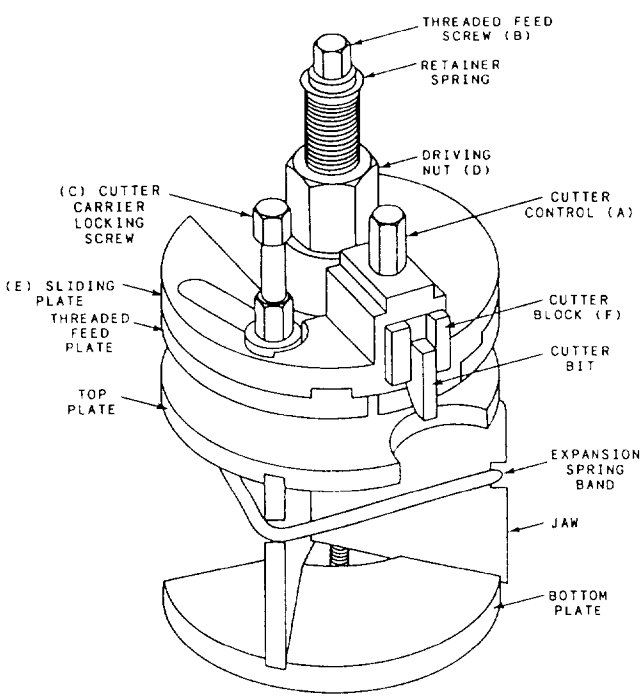


Figure 2-16.—A typical ridge reamer.

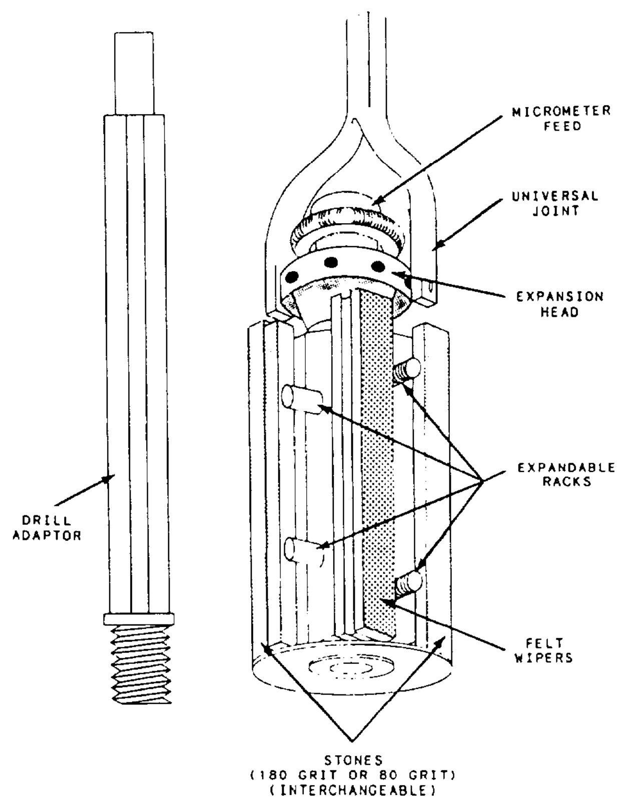


Figure 2-17.—A typical cylinder hone.

ENGINE TEST EQUIPMENT

When an engine has been repaired or overhauled, it may need to be tested for proper operation and power output. **A** piece of test equipment used to conduct such tests is the dynamometer. The following is a basic explanation of how a dynamometer works. For in-depth information about this test equipment, refer to the manufacturer's manual.

The dynamometer is used to apply specific loads to an engine. It allows the technician to inspect and check the engine while it is operating. The dynamometer absorbs and measures the engine's output. The basic components of a dynamometer are the frame, engine mounts, absorption unit, heat exchanger, and torque and measuring device. To properly operate a dynamometer you must complete a shop qualifications course. Dynamometers are found primarily in shore activity shops. For maintenance, refer to assigned PMS for the equipment. If your shop has no PMS maintenance for the dynamometer, follow the maintenance schedule recommended by the manufacturer.

SUMMARY

In this chapter, you have learned to identify the necessary measuring and repair instruments and their basic components and how to use them. Additionally, you have learned basic information about the dynamometer, its operation and maintenance. For additional information about basic measuring and repair instruments and the dynamometer, refer to each item's manufacturer's manual, assigned PMS, and your work center's shop equipment qualifications program.